

## OPTICAL INTERFERENCE TYPE OF COLOR DISPLAY

### DESCRIPTION

#### CROSS-REFERENCE TO RELATED APPLICATION

[Para 1] This application is a divisional of a prior application serial no. 10/249,243, filed on March 26, 2003, which claims the priority benefit of Taiwan application serial no. 91137264, filed on December 25, 2002.

#### BACKGROUND OF THE INVENTION

[Para 2] Field of Invention

[Para 3] The present invention relates to an optical interference type of color display. More particularly, the present invention relates to an optical interference type of color display having an improved color shift and contrast ratio (CR).

[Para 4] Description of Related Art

[Para 5] At present, lightweight and slim flat panel displays such as liquid crystal display (LCD), organic light-emitting device (OLED) or plasma display panel (PDP) are widely adopted in our everyday life. In particular, liquid crystal panels have become one of the mainstream displays. However, most LCD still has a number of drawbacks including narrow visual angle, moderate response time, need for a color filter for full

coloration, and need for a polarizer leading to a poor optical utilization of light source and energy wastage by a back light module.

[Para 6] To improve the operating efficiency of LCD, a new type of LCD called an optical interference display is developed. The optical interference panel comprises an array of optical interference modulators. Each optical interference modulator includes a transparent electrode, a reflective electrode and a support layer for supporting the reflective electrode. Through the support of the support layer, an air gap with a specified thickness is formed between the reflective electrode and the transparent electrode. Light entering from the transparent electrode of the optical interference modulator passes through the air gap and impinges upon the second electrode. Light impinging the second electrode is reflected back to emerge from the modulator through the transparent electrode. Because light passing through air gap of different thickness may result in different degree of optical interference, different colors are produced. For example, red light, green light and blue light can be produced in this way. In addition, the design of the reflective electrode inside the optical interference modulator must integrate with a micro-electromechanical system (MEMS) so that the optical interference modulator can switch between an 'on' or an 'off' state to illuminate or darken a spot on the panel.

[Para 7] The aforementioned optical interference modulators inside the optical interference display need no additional coloring filter or polarizer for producing a suitable color point and hence able to save some production cost. In addition, each optical

interference modulator consumes very little electric power, quick to respond to electrical signals and operates in a bi-stable state. Therefore, the optical interference display is suitable for low power consumption products including most portable device such as mobile phone, personal digital assistant (PDA), electronic book (e-book) and so on.

[Para 8] Fig. 1 is a schematic sectional view of a conventional optical interference color display structure. As shown in Fig. 1, the optical interference color display 100 mainly comprises a transparent substrate 110, a patterned support layer 120, a plurality of first electrodes 130, a plurality of optical films 140 and a plurality of second electrodes 150. In general, the transparent substrate 110 is a glass substrate or a substrate made from a transparent material. The patterned support layer 120 is positioned on the transparent substrate 110 for supporting the edges of the second electrodes 150. The first electrodes 130 are also positioned on the transparent substrate 110. The first electrodes 130 are transparent electrodes fabricated using a material including indium-tin-oxide (ITO). The optical film 140 is positioned on the first electrodes 130. Typically, the optical film 140 is a composite stack having a multiple of alternately positioned high dielectric constant films and low dielectric constant films. The second electrodes 150 are positioned over the first electrodes 130. Through the support of the patterned support layer 120, the second electrodes 150 are positioned over the first electrodes 130. The second electrodes 150 are typically fabricated using a highly reflective metallic material.

[Para 9] In general, a conventional optical interference color panel comprises a plurality of optical interference modulators each having a different air gap thickness. As shown in Fig. 1, the air gap between the second electrode 150 and the first electrode 130 is different for different optical interference modulators. To produce color light, the optical interference modulators are designed to have three different air gap separations  $d_1$ ,  $d_2$  and  $d_3$ . The optical interference modulator with an air gap separation of  $d_1$  emits red light; the optical interference modulator with an air gap separation of  $d_2$  emits blue light; and, the optical interference modulator with an air gap separation of  $d_3$  emits green light. In other words, as light coming from outside penetrates through the transparent substrate 110, the first electrodes 130 and the optical films 140, the light needs to pass through different air gap thickness  $d_1$ ,  $d_2$ ,  $d_3$  before arriving at the respective second electrodes 150. Thereafter, the light emerges from the transparent substrate 110 after reflecting back by the second electrodes 150. Due to different degree of interference at different air gap thickness, red light, green light and blue light are produced.

[Para 10] In a conventional optical interference modulator, the second electrode 150 must be fabricated using a reflective material with good mechanical properties. When the second electrode 150 and the first electrode 130 are coupled to a bias voltage, the second electrode 150 may shift towards the first electrode 130 due to electrostatic attraction. Any movement of the second electrode 150 may lead to a slight variation of the air gap  $d_1$ ,  $d_2$  and  $d_3$ . Through a slight change in the thickness of the air gaps  $d_1$ ,  $d_2$ , and  $d_3$ , various optical

interference modulators (pixels) within the display can be switched to an 'on' or an 'off' state.

[Para 11] In the optical interference color display 100, images on display may be affected by user's viewing angle due to an intensification of color shift and a deterioration of contrast ratio. Thus, the conventional technique often demands the attachment of an optical diffusion plate 160 to the outer surface of the transparent substrate 110 for improving color shift and contrast ratio. However, the attachment of an optical diffusion plate not only increases the overall thickness of the color display 100 (an additional thickness of about 2mm), but also increases material cost.

## SUMMARY OF THE INVENTION

[Para 12] Accordingly, one object of the present invention is to provide an optical interference color display having an improved color shift and contrast ratio by forming layers of films inside a panel instead of attaching an optical diffusion plate outside the panel.

[Para 13] To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides an optical interference color display. The optical interference color display mainly comprises a transparent substrate, an inner-front optical diffusion layer, a plurality of first electrodes, a patterned support layer, a plurality of optical films and a plurality of second electrodes. The inner-front optical diffusion layer is positioned on the transparent substrate. The first electrodes are positioned on the inner-front optical diffusion layer. The patterned support layer is also

positioned on the inner-front optical diffusion layer but between the first electrodes. The optical films are positioned over the first electrodes. The second electrodes are positioned over the respective first electrodes and supported by the patterned support layer. In addition, there is an air gap between each first and second electrode pair.

[Para 14] In this embodiment, the inner-front optical diffusion layer includes, for example, a first film and a second film. The first film is directly attached to the transparent substrate and the second film is positioned on the first film. The interface between the first film and the second film further provides a dispersive surface. The first film is fabricated using indium-tin-oxide and the second film is fabricated using silicon nitride or silicon oxide, for example.

[Para 15] In this embodiment, the surface of second electrode facing the first electrode may further include an inner-back optical diffusion layer. The inner-back optical diffusion layer is fabricated on the optical interference color display in the same process as fabricating the inner-front optical diffusion layer. Furthermore, this invention also permits the formation of the inner-back optical diffusion layer without an inner-front optical diffusion layer.

[Para 16] In this embodiment, the inner-back optical diffusion layer is supported by the patterned support layer and separated from the first electrode by an air gap. The inner-back optical diffusion layer includes, for example, a third film and a fourth film. The third film is directly attached to the first electrode and the fourth film is positioned over the third film. The interface

between the third film and the fourth film further provides a dispersive surface. The third film is fabricated using indium-tin-oxide and the fourth film is fabricated using silicon nitride or silicon oxide, for example.

[Para 17] In this embodiment, the transparent substrate is, for example, a glass substrate. The first electrodes are transparent electrodes fabricated using, for example, indium-tin-oxide. The second electrodes are metallic electrodes fabricated using, for example, molybdenum, molybdenum alloy, aluminum, aluminum alloy, chromium or other conductive metallic materials.

[Para 18] In this embodiment, the optical film comprises, for example, at least a first dielectric film and at least a second dielectric film. The second dielectric film and the first dielectric film are alternately stacked over each other. The second dielectric film has a dielectric constant that differs from the first dielectric film.

[Para 19] This invention permits selective deployment of an inner-front optical diffusion layer and an inner-back optical diffusion layer. The optical diffusion layer replaces the attached optical diffusion plate structure in a conventional design and improves display properties including the color shift and contrast ratio.

[Para 20] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

## BRIEF DESCRIPTION OF THE DRAWINGS

[Para 21] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[Para 22] Fig. 1 is a schematic sectional view of a conventional optical interference color display structure;

[Para 23] Fig. 2 is a schematic sectional view of an optical interference color display structure according to a first preferred embodiment of this invention;

[Para 24] Fig. 3 is a schematic sectional view of an optical interference color display structure according to a second preferred embodiment of this invention; and

[Para 25] Fig. 4 is a schematic sectional view of an optical interference color display structure according to a third preferred embodiment of this invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[Para 26] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[Para 27] Fig. 2 is a schematic sectional view of an optical interference color display structure



according to a first preferred embodiment of this invention. As shown in Fig. 2, the optical interference color panel 200 mainly comprises a transparent substrate 210, an inner-front optical diffusion layer 300, a patterned support layer 220, a plurality of first electrodes 230, a plurality of optical films 240 and a plurality of second electrodes 250. The inner-front optical diffusion layer 300 is positioned over the transparent substrate 210 covering the entire surface of the transparent substrate 210, for example. The patterned support layer 220 is also positioned over the transparent substrate 210 for supporting the edges of the second electrodes 250. The first electrodes 230 are positioned on the transparent substrate 210. The optical films 240 are positioned on the first electrodes 230. The second electrodes 250 are positioned over the respective first electrodes 230 and supported through the patterned support layer 220.

[Para 28] In this embodiment, the transparent substrate 210 is, for example, a glass substrate or a substrate made from some other transparent materials. The patterned support layer 220 may include a plurality of cylindrical bodies fabricated using, for example, resinous material. The first electrodes 230 are transparent electrodes fabricated using, for example, indium-tin-oxide (ITO). The optical film 240 includes, for example, at least a first dielectric film 240a and a second dielectric film 240b alternately stacked over each other. The second dielectric film 240a has a dielectric constant that differs from the first dielectric film 240b. Since the second electrodes 250 serves as reflective electrodes, the second electrodes 250 must have good mechanical properties. Hence, the second electrodes 250

are fabricated using a sturdy material including, for example, aluminum or an alloy of aluminum.

[Para 29] To produce a color display, the optical interference modulators inside the optical interference color panel 200 are fabricated with one of three different air gap thickness ( $d_1$ ,  $d_2$  and  $d_3$ ). For example, an optical interference modulator having an air gap thickness of  $d_1$  emits red light. Similarly, an optical interference modulator having an air gap thickness of  $d_2$  emits blue light and an optical interference modulator having an air gap thickness of  $d_3$  emits green light. In other words, external light passing through the transparent substrate 210, the inner-front diffusion layer 300, the first electrode 230 and the optical film 240 will have to pass through an air gap of different thickness ( $d_1$ ,  $d_2$ ,  $d_3$ ) before reacting the second electrode 250. Thereafter, the light is reflected back from the second electrode 250 to emerge as an output beam through the transparent substrate 210. Due to a different degree of interference through the optical path, red, green and blue light are produced accordingly.

[Para 30] In general, the second electrode 250 serves as a reflective electrode and has good mechanical properties. When a bias voltage is applied between the second electrode 250 and the first electrode 230, the second electrode 250 will move slightly towards the first electrode 230 due to electrostatic attraction. Such movement changes the air gap  $d_1$ ,  $d_2$  or  $d_3$  inside the optical interference modulator. In other words, through a change in the air gap thickness  $d_1$ ,  $d_2$  or  $d_3$  inside the optical interference modulator, the 'on' state or the 'off' state of optical interference modulators (pixels) is set.

## [Para 31]

To improve color shift and reduce contrast ratio deterioration, this invention also provides an inner-front optical diffusion plate 300 on the transparent substrate 210. The inner-front optical diffusion plate 300 includes, for example, a first film 302 and a second film 304. The first film 302 is attached to the transparent substrate 210 and the second film 304 is positioned over the first film 302. The interface between the first film 302 and the second film 304 provides a dispersive surface. The first film 302 is fabricated using a material including, for example, indium-tin-oxide. The second film 304 is fabricated using a material including, for example, silicon nitride or silicon oxide. In addition, the inner-front optical diffusion plate 300 is formed over the transparent substrate 210, for example, by conducting a plasma-enhanced chemical vapor deposition (PECVD) with the processing conditions shown in Table 1 below.

Table 1

	Gas flow rate of reactive gases	Power rating	Thickness	Temperature
Indium-tin-oxide (ITO) reaction	Ar: 100 sccm O <sub>2</sub> : 1.0 sccm	3.4 kW	420Å	Room Temperature
Silicon nitride indium-tin-oxide reaction	N <sub>2</sub> : 5000 sccm HN <sub>3</sub> : 2000 sccm SiH <sub>4</sub> : 350 sccm	2100 kW	6000Å	380°C

[Para 32] Fig. 3 is a schematic sectional view of an optical interference color display structure according to a second preferred embodiment of this invention. As shown in Fig. 3, an inner-back optical diffusion layer 400 is formed on the surface of the second electrode 250 facing the first electrode 230. The inner-back optical diffusion layer 400 is supported by the patterned support layer 220 and separated from the first electrode 230 by an air gap thickness of  $d_1$ ,  $d_2$  or  $d_3$ . The inner-back optical diffusion layer 400 comprises, for example, a third film 402 and a fourth film 404. The third film 402 is positioned over the first electrode 230 and the fourth film 404 is positioned over the third film 402. The interface between the third film 402 and the fourth film 404 provides a dispersive surface. The third film 402 is fabricated using a material including, for example, indium-tin-oxide. The fourth film 404 is fabricated using a material including, for example, silicon nitride or silicon oxide.

[Para 33] Fig. 4 is a schematic sectional view of an optical interference color display structure according to a third preferred embodiment of this invention. As shown in Fig. 4, the optical interference color display has a structure similar to the first and the second embodiment. One major difference is that an inner-front optical diffusion layer 300 and an inner-back optical diffusion layer 400 are formed inside the optical interference color panel 200. After integrating the inner-front optical diffusion layer 300 and the inner-back optical diffusion layer 400, color shift and contrast ratio deterioration are improved leading to a better overall performance in the optical interference color panel 200.

[Para 34] In conclusion, the optical interference color pane has at least the following advantages:

[Para 35] 1. The inner-front optical interference layer and the inner-back optical interference layer can be selectively employed or both can be used together to supplant the conventional attached optical diffusion plate so that both color shift and contrast ratio deterioration are improved.

[Para 36] 2. The inner-front optical diffusion layer and/or the inner-back optical interference diffusion layer can be fabricated by conducting a plasma-enhanced chemical vapor deposition. This method of fabrication is more effective in controlling the optical properties including dispersion of various optical diffusion layers. In other words, overall luminance of the panel is increased.

[Para 37] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.